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VISION 2040: EVOLVING THE SUCCESSFUL INTERNATIONAL SPACE UNIVERSITY DECADES INTO THE FUTURE

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Space exploration has always been full of inspiration, innovation, and creativity, with the promise of expanding human civilization beyond Earth. The space sector is currently experiencing rapid change as disruptive technologies, grassroots programs, and new commercial initiatives have reshaped long-standing methods of operation. Throughout the last 28 years, the International Space University (ISU) has been a leading institution for space education, forming international partnerships, and encouraging entrepreneurship in its over 4,000 alumni. In this report, our Vision 2040 team projected the next 25 years of space exploration and analyzed how ISU could remain a leading institution in the rapidly changing industry. Vision 2040 considered five important future scenarios for the space sector: real-time Earth applications, orbital stations, lunar bases, lunar and asteroid mining, and a human presence on Mars. We identified the signals of disruptive change within these scenarios, including underlying driving forces and potential challenges, and derived a set of skills that will be required in the future space industry. Using these skills as a starting point, we proposed strategies in five areas of focus for ISU: the future of the Space Studies Program (SSP), analog missions, outreach, alumni, and startups. We concluded that ISU could become not just an increasingly innovative educational institution, but one that acts as an international organization that drives space commercialization, exploration, innovation, and cooperation.

I. INTRODUCTION

A lot can happen in 25 years.

The world of 1990 was a much different place than the one we live in today. Geopolitically, the Cold War was still in its death throes and nations like China and India were still emerging powers[1]. Technologically, what would be called the Internet was just beginning to revolutionize global communications and culture[2] and the Hubble Space Telescope—that eventual harbinger of astronomical and astrophysical discoveries that would upend our widely held assumptions about the universe—was just leaving the launch pad[3]. Space exploration itself was largely assumed to be a government affair, with a smattering of private interests finding niches that would one day grow in significance. For a space-focused educational institution like the International Space University (ISU), then only three years old[4], the future, or futures as they would have seemed, were full of equal amounts of possibility and uncertainty.

At this point in time, we found ourselves once again looking towards the future, tasked with determining not only what kind of changes the coming quarter of a century might bring, but also what niche an organization like our ISU summer host could fill. United through ISU's Space Studies Program (SSP) at Ohio University, we intended not to forecast specific developments that we are certain to develop, but to observe ongoing trends—their signals and drivers—that might allow us to forecast what futures are possible and to help us plan and work towards the futures we want. As Jim Dator would say, "The future cannot be predicted because the future does not exist" and "Any useful ideas about the futures should appear to be ridiculous"[5]. In our mission to better understand potential futures, we realized that we would have to consider the pragmatic as well as the idealistic, the realistic as well as the fantastic.

The goal of the Vision 2040 team project was to envision the evolution of education, science, space activities, and culture, to create strategies the International Space University (ISU) could implement to prepare future space professionals to succeed. In addition to ISU, the study received sponsorship from the National Aeronautics Space Administration (NASA), the European Space Agency (ESA), and the Centre National d'Études Spatiales (CNES), as well as commercial corporations such as The Aerospace Corporation, Lockheed Martin Corporation, and The Boeing Company. Each of these ISU stakeholders naturally had an interest in the future of space education and the potential graduates that might one day join or even lead the stakeholder organizations. To this end, we envisioned the state of the space industry in 2040 and how ongoing changes would affect national space agencies, aerospace companies, engineering companies, ISU alumni, and future ISU participants, through a method described in Figure I-1.

Focusing on both the current and potential stakeholders, we provided roadmaps and actionable strategies for ISU to build on its strong reputation as a force in the space sector at the forefront of innovation, education, space policy, and international relations. These strategies were identified through the analysis of scenarios forecasted to be characteristic of space activity in the year 2040, as seen in Figure I-1, including real-time Earth observation, Earth orbital stations, a lunar settlement, lunar and asteroid mining, and a human presence on Mars. After researching current innovative and disruptive technologies likely to impact the space sector before 2040, we developed a plan for ISU to embrace these developments. We reviewed how current external developments affected the space industry, underwent visioning exercises with experts in futures studies including Dator, and considered how ISU might adjust to an ever-changing political, social, and economic climate.

Through this research, we identified skill and knowledge gaps within each envisioned scenario, creating a representative list of skills that would be desirable in future space professionals. We used this list to identify five primary areas of focus for ISU: the future of the SSP program, the potential of analog missions, the need for outreach both inside and outside the space sector, the resource capabilities of the alumni network, and the possibility for greater co-operation between ISU and space startup companies. By developing these areas of focus, ISU would draw benefits for itself, its stakeholders, and its participants. Through implementing this 25-year strategy with short-term and long-term results, we believe that ISU will continue to be a world-renowned center of excellence for space studies by the year 2040.
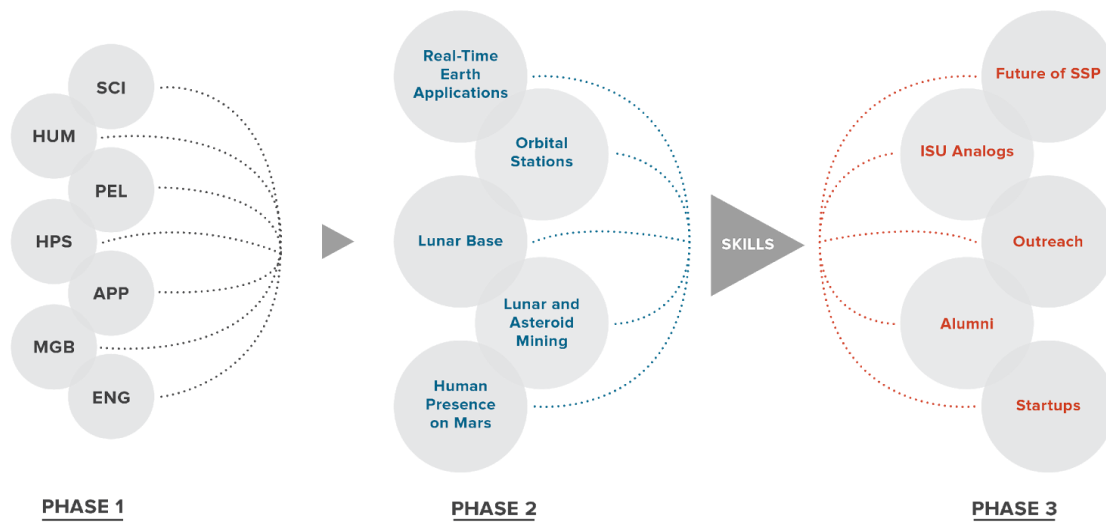
Figure I-1: Methodology used for the different phases of the Vision 2040 study. The acronyms in phase I stand for the seven ISU departments: science (SCI), engineering (ENG), humanities (HUM), policy, economics and law (PEL), space applications (APP), management and business (MGB) and human performance in space (HPS).

II. SCENARIOS

II.I. Real-time Earth Applications

The satellite industry and its applications represent the largest portion of today's space industry, accounting for over 60% of the total revenue of the global space industry[6]. Space-based Earth observation has changed society's lives dramatically, thanks to the ability to reliably predict climate variability and change over oceans and landforms[7]. Nonetheless, the majority of this market is in the satellite telecommunication industry, with a market of over $100 billion, primarily from satellite television providers[6].

The number of nanosatellites has increased by a factor of six in the past five years, with a total of over 120 in 2014 alone[6]. In 2015, ESA announced it would offer transportation to the asteroid belt for six CubeSat designs[8], and NASA announced a $5 million campaign for the development of CubeSat technologies[9]. Initiatives bringing greater Internet access to less connected parts of the world have become a transformative trend. These initiatives include Google's high-altitude balloons, Project Loon[10], Facebook's Internet.org[11], and networks like O3b[12] and OneWeb[13], which aim to use satellite constellations to connect developing countries to the global communication grid. For 2040, we can forecast that real-time, low-cost applications will become publicly available thanks to the development of commercial remote sensing satellite systems. These systems would allow for better management of disasters, as well as improved biosphere and weather forecasting capabilities[14].

One of the biggest challenges for future space applications near Earth is the increasing amount of space debris in Earth's lower orbit. Currently, there are more than 400,000 objects as large as a centimeter or more in Low Earth Orbit (LEO)[15]. This problem could become worse with the rapid increase in CubeSat launches, leading to the accumulation of orbital hazards from defunct satellites.

The increase in spatial, temporal and spectral resolutions also poses a challenge for Earth observation systems. More data does not necessarily mean better science and applications, particularly if we are unable to effectively analyze it[16]. Another challenge is the amount of spectrum that regulatory bodies, such as the International Telecommunication Union (ITU), would be willing to preserve or allocate for space activities.

CubeSat technology is valued by universities, corporations, and government organizations[17]. Using CubeSats, universities can give their teachers and students a more practical and interdisciplinary learning experience in every phase of a satellite mission[18]. In the context of new policy, the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) has set up the Working Group on Long Term Sustainability of Outer Space Activities to develop and evaluate practices and policies relevant to space environment sustainability[19]. However, UN COPUOS only provides voluntary guidelines for reducing the creation of orbital debris. The research community has proposed several different techniques to accelerate the post- mission disposal of satellites.

Current approaches based on passive mitigation techniques include drag sails, balloons, and tethers. Active removal techniques, such as missions proposing the use of robotic arms to de-orbit inactive satellites, pose a number of political challenges, as they can be seen as dual-use technology.

II.II. Orbital Stations

In the year 2040, we envision space-based orbital stations serving a variety of commercial and research applications. In addition to current facilities for scientific research and communication, the private and public sector will both build and operate new facilities for education, tourism, industry, and culture.

The space race, and its transition to international cooperation, resulted in the development and success of orbital stations like Mir, Skylab, ISS and now Tiangong. These collaborations greatly pushed the boundaries of space science and engineering.

Scientific research prefers using space laboratories, observatories, telescopes, and other instrumentation in orbit, to avoid the effects of Earth's atmosphere and gravity[20]. The unique orbital environment offers an important platform for scientific experiments and astronomy.

Recently, there is also growing interest in commercial space. Many companies like Bigelow Aerospace, Orbital Technologies, Urthecast, Planetary Resources and Nanoracks have been planning or working on space stations and commercial activities using orbital base[21,22,23]. In the future, more CubeSat and nanosat companies would also prefer to build and deploy satellites from space stations rather than commissioning dedicated launches from Earth[24].

The increased interest in commercial space applications and the scientific endeavors by the research community are the major signals and drivers for upcoming orbital stations.

The main challenges we observed in achieving the above objectives include low cost access to space, formulation of appropriate policies and amendments in space laws and technology transfer by space agencies to private players.

The various skills required to achieve the above scenarios includes STEAM education, international cooperation among space faring nations with a promising leadership, cost effective advanced technologies in spacecraft and propulsion systems and finally good business models with provisions for negotiations rather than taking legal routes.

II.III. Lunar base

One of our scenarios features a return to the Moon and the foundation of a human settlement. By 2040, 71 years will have passed since humanity first landed there on the Apollo 11 mission. Our lunar base vision includes a variety of parallel opportunities for further lunar research, industry, and tourism, as well as an intermediate space station.

Lunar research refers to "lunar scientific exploration involving three types of investigations: science of the Moon, science from the Moon, and science on the Moon"[25]. We will use this research to better understand Earth's largest natural satellite and to gain the knowledge necessary to advance humanity further into space.

A settlement will be a vital part of the lunar base. This settlement can serve as accommodation for a permanent or temporary community to support the industry, as a research facility, an intermediate station for deep space exploration, and can be the base for lunar tourism. We could use a viable lunar settlement to preserve humanity's existence in the event of an extinction level cataclysm on our home planet.

The Moon could also serve as an intermediate stage in planetary exploration. The idea is to make outer space more accessible, the journey more efficient, overcome payload and cargo limitations, and lower the costs by a layover in the lunar base. Lunar tourism envisages also improving public outreach by inspiring more people to explore space.

The signals and drivers are the elements pushing this scenario forward. We have identified different signals demonstrating an interest among countries, companies, and members of the public in settling the Moon[26,27]. The Google Lunar XPRIZE[28] and other design challenges are capturing the attention of existing companies or helping fund new ones, boosting the public awareness of these kinds of missions.

The challenges facing the establishment of a future lunar base are primarily technical, as well as getting financial support from governments and the public.

The creation of a lunar base requires development of several advanced spacecraft technologies. Demand for the transportation of materials, equipment, and facilities between the Moon and Earth will increase. To transport those payloads, we need to develop a heavy-lift space vehicle, whose capabilities might exceed current launch vehicles. Currently unused propulsion technologies, such as nuclear propulsion[29], might be required to achieve these goals.

A research settlement and tourism activities will require new structures and the construction of habitable sites for long-term or permanent settlement. The life support and recycling systems, especially ones that take advantage of on-site resources, will be critical for humans to maintain an everyday existence on the Moon or perform extravehicular activities.

II.IV. Lunar and Asteroid Mining

Space exploration has the inherent benefit of potentially allowing access to a vast supply of untapped resources. As space access increases, resources in limited supply on Earth can be augmented by resources from space.

In the coming 25 years, space-based resource extraction and utilization will greatly reduce the cost and complexity of space exploration and reduce environmental damage on Earth.

We have identified that changes in regulatory legislation to specify the ownership of asteroid resources[30], increased public and private activities in missions to celestial bodies[31,32,33,34,35,36,37,38], and the development of technologies such as ISRU[39] and 3D printing[40] are the signals and drivers of change in lunar and asteroid mining.

The space sector workforce will require a versatile skillset to address the technical, political and economical challenges of lunar and asteroid mining. First, greater focus is needed on scientific and technical education particularly in the fields of: space systems engineering, chemistry, geology, mining, space-based manufacturing, environmental science, robotics, and aerospace. Second, space policy and international cooperation will continue to be a major challenge for mining space-based resources. Future space leaders will require a solid knowledge of international law and political science both in the private sector and in national space agencies. In this globalized political landscape, communication and negotiation skills will be key to promoting international cooperation, prioritizing missions, as well as negotiating budgets and partnerships.

II.V. Human Presence on Mars

By the year 2040, we envision that humanity will have set foot on Mars. We believe this mission will be the culmination of years of international collaboration and will involve landing on and exploring the surface, as well as returning safely home to Earth. Humankind's first steps on the Martian surface may also pave the way for a subsequent permanent presence on Mars.

For the mission to be successful, a few signals of change and their governing drivers must remain consistent over the next 25 years. Newly available commercial opportunities in space are driving an increase in investments and in public-private partnerships in the business of space. Likewise, international cooperation has driven a greater sharing of budget costs and political risk, as well as joint technological development. Research advances in life support technology, as well as human physiology and psychology in space, have mitigated but not solved the problems posed by resource management, food production, radiation exposure, muscle and bone mass loss, and pressure on mental health. Research and development of new propulsion systems should lead to reductions in the cost and time of spaceflight, larger payload capacities, and greater capabilities of thrust, impulse, and reusability.

Any potential crewed mission to Mars must address challenges related to culture, policy and technology, as well as the underlying challenge of funding. Continued media interest, and by extension interest from the public, in human exploration of Mars is critical to any mission being funded. The estimated cost of a mission to Mars is between $6 billion[41] and $450 billion[42], with the primary costs derived from the need for a return and the complexity of the mission. In terms of policy, human missions to Mars will probably require an international collaboration similar to the framework governing the ISS[43]. The development of the NewSpace economy will require more initiatives from individuals and companies, as well as the advancement of available space technologies. There are still technological limitations to be overcome, including the development of advanced propulsion systems, radiation shielding for astronauts, telemedicine, ISRU, long duration mission life support systems, and 3D printing of a variety of materials.

While a crewed mission may not occur until the 2030s or 2040s, relevant skills need to be developed by the international community now to address the challenges associated with going to Mars. The culture, policy, and technology challenges faced can be surmounted by developing skills across competencies including education, crew selection and training, advanced spacecraft technology, in situ resource utilization, and life support systems. For instance, the international collaboration challenges may require improving STEAM education. Startups could provide real hands-on learning for business and arts professionals. In addition, effective public outreach of a crewed mission to Mars will make that mission more likely to succeed.

III. STRATEGIES

III.I. Alumni

The main goal was to activate as many alumni as possible into leading ISU into the future, through three main strategies, each with a number of initiatives and specific implementation plans. These strategies included strengthening and building existing alumni connections, as well as widening the alumni role in ISU guidance and in the creation of applied projects inside ISU.

The Global Network

We proposed strengthening existing connections and building new ones between different ISU generations through a mentor-mentee system. This would extend the network and give alumni the opportunity to meet each other, share information, or create partnerships for new ventures. Another initiative could be a skills database of alumni, as well as partners and stakeholders such as space agencies or companies.

Alumni Associations

National and even regional alumni organizations must be the main driver in building and growing the global alumni organization. They are organized by alumni, and offer many opportunities. Depending on the local situation, evening events with sponsors, introductions about SSP and the ISU curriculum in general can be ways to attract both alumni and interested people.

Together with the ISU Main Campus, the alumni organizations can organize an annual conference. In tandem with the presentation of current research topics out of the community, a renewal of space specific knowledge could be addressed. To commit to the international character of ISU, the conference could be hosted in several locations as well as virtually via video conferencing systems.

The possibility of situating the alumni conference within another broader ISU space conference in association with successful events[44] like Web Summit in Ireland, TED, South By Southwest in Texas, C2SV in California, or RISE in Asia should be analyzed.

Alumni representatives on the board of trustees

We suggest widening the role of global alumni in ISU guidance. There is currently an alumni representative on the ISU board of trustees, whose main responsibility is to represent the ISU alumni at board meetings. There is a class representative elected from every graduating class of SSP and MSS programs but there are currently no formal committees between the alumni representative on the board of trustees and the class representatives[45]. The alumni representative should consider expanding their responsibilities to liaise with class representatives directly.

It was also proposed that ISU maintains the one-week Executive Space Course and reinstates the 12-day Space Odyssey Institute[46]. While their operation depends heavily on funding, they are a valuable means for ISU to align with space sector companies and institutions and enhance the prestige of the alumni network. Additionally, ISU should consider engaging its alumni to participate in STEAM activities, such as outreach events, to increase its profile among the global alumni community. Applied team projects could help students gain work experience.

ISU has always played an important role in gathering together influential policy makers, scientists, business leaders and other space professionals inside its strong alumni and faculty network. The analyzed scenarios in this report demand an even wider ISU influence. All the skills, like communication, negotiation, and international policy and law, are studied at ISU. Broadening and extending courses to enable students to learn these skills, is an integral part of activities and the ISU curriculum.

ISU must adapt to trends in the space sector and the alumni are a key resource for that adaptation, as they are best positioned to bridge the gap between the academic world of ISU and the worlds of companies and organizations around the world. The 3Is principle is intrinsic to ISU's success and this interdisciplinary, international, and intercultural approach is reflected in ISU's alumni. However, a more flexible approach to the 3Is, where disciplinary and slightly more exclusive initiatives are created, should be adopted when planning national ISU alumni initiatives, and designing other events that target specific audiences for specific events.

As ISU is an educational institution, its alumni are one of its major partners and stakeholders. The connections created during the participation in ISU programs are also beneficial to other stakeholders, such as the private sector and space agencies. Through engaging the alumni, ISU can affect future stakeholders some of which will be graduates themselves or their direct connections. As an international, intercultural, and interdisciplinary entity with alumni in a majority of the world's key space players, ISU would have a unique opportunity to affect these players and create partnerships with both existing and new institutions.

The ISU alumni strategies proposed target the role of alumni as guiding the wider global space sector and as well as ISU itself. Engaged alumni are necessary for the success and expansion of ISU in the next 25 years, as shown in the roadmap of Figure III-

1. This will enable ISU to become a world leader in educating future space leaders, and a strong influencer of policy makers, scientists and businesses. Maintaining a strong alumni network will be the main challenge. Multiple strategies have to be implemented in parallel, to gain the most out of them. ISU has to bring its alumni together, and strengthen its bond to important peer groups in research and the commercial area.
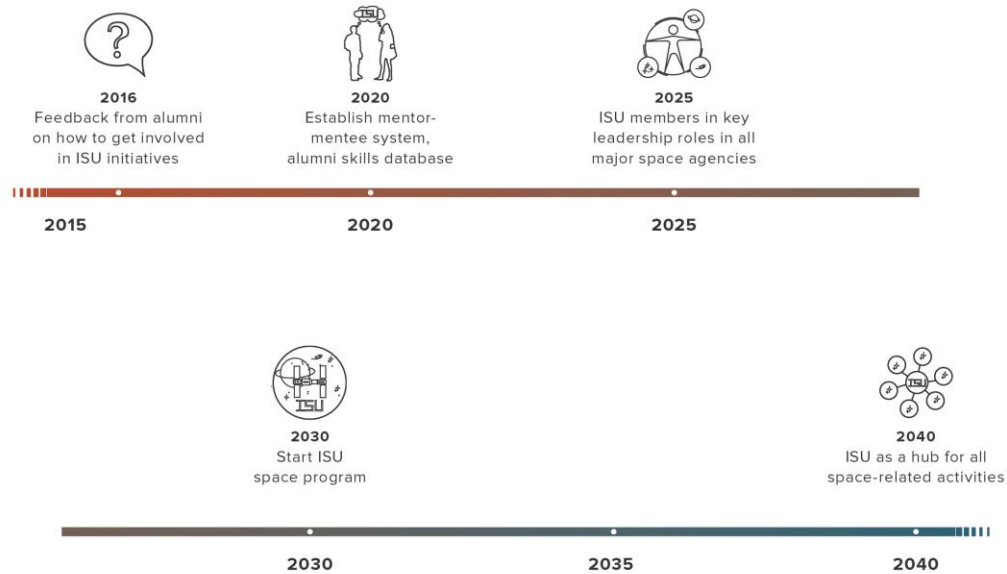

Figure III-1: 25-year roadmap for the Alumni strategy

III.II. The Future of SSP

By incorporating online education technologies into its flagship program, the SSP, ISU will both increase outreach and branding, and enable a tailored experience focused on advanced technologies and future trends. For ISU to remain an innovative educational institution, it must increase and improve on its online presence and start online education.

SSP will be divided into two sections, one online and the other offline. Together they would include more outreach, technology education, hands-on experiences, and connections with the actual space sector. It will be the natural evolution of ISU's emblematic program into the most prestigious exemplar program for the space sector.

The online section will make use of emerging trends and disruptive technologies in the communication and education fields, such as online courses and virtual reality (VR).

The whole SSP program will be able to focus on applied learning, preparing the ISU participants to be leaders in advanced spacecraft technology, space policy, public outreach, and entrepreneurship. This will include a new series of distinguished lectures on cutting-edge technology, replacing the current core lectures, as these would be transitioned into the online section of SSP. Top-level experts in specific fields will explain ongoing and future research projects. These lectures will be recorded and added to the alumni database after the SSP. ISU alumni will continually advance their knowledge with newer material, such as videos, texts, and audio recordings, released after the end of an SSP session.

The participants will select from a greater variety of workshops, expert panels, and theme days. There will be more hands-on experiences using disruptive technologies and an on-going examination of future trends. Using data gathered during the online part, the SSP will become a tailored experience. Each participant will be offered a list of initial suggestions for courses, lectures, workshops, theme days, and hands-on experiences that the data suggests will provide the participants with a more meaningful and applied learning experience. Each participant will engage with professionals in their field of interest through networking sessions.

ISU should consider upcoming changes in educational methods. It must adapt by identifying the drivers of change, acquiring skills in a timely manner, and offering new forms of education. Education methods of the future will be changed drastically by drivers such as the democratization of knowledge and

access, instability of markets and funding, digital technologies, global mobility, and integration with industry[47].

Applying this strategy will completely transform the SSP into a new program capable of tackling challenges posed by our future scenarios. These include the need for global education and outreach, a more technically educated workforce, and an increased public interest in the space sector. The new online and offline strategy for the SSP will provide ISU alumni with better skills in cutting-edge technologies, like AI and 3D printing, thanks to the tailored educational approach.

ISU should change its educational program to intensify relations with key stakeholders. The alumni network, national space programs, and the private space industry all stand to benefit from more highly educated ISU students who have hands-on experience in space-related activities. Online education will allow a greater number of people from more diverse backgrounds to encounter and have access to ISU educational material, which will also increase the visibility of ISU and the space industry. The wider student body, and the data that can be gained from

online course work, can also be used by the industry and space agencies to determine the existing skillsets of the general population.

The online revolution has already affected the education sector and will become even more transformative in the coming years. With the use of improved big data processing techniques and VR technologies, the educational sector will be completely transformed by 2040. ISU should incorporate the latest technologies to transform the SSP into a more learning-intensive experience, with more focus on hands-on experiences and the latest technology trends, as suggested in the roadmap of Figure III-2. These recommendations are applicable to any other kind of educational institution that wants to transform its programs into a more hands-on and tailored approach by leveraging digital technologies. These institutions and their stakeholders will benefit from better outreach, branding, and improved learning outcomes for the students. This will result in a larger, more tech-educated and interconnected alumni workforce, who will be able to tackle the challenges ahead by mobilizing international efforts.
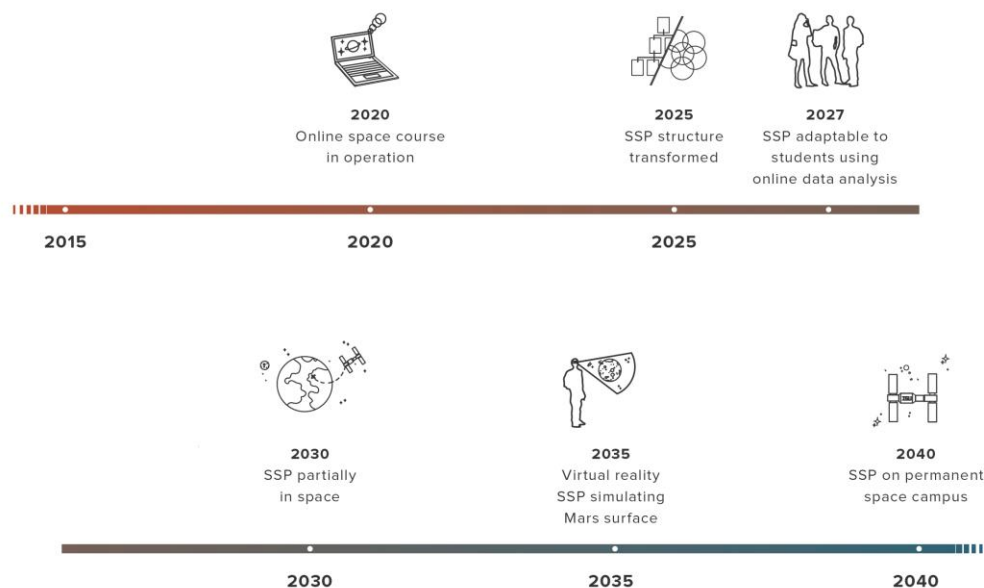

Figure III-2: 25-year roadmap for the Future of SSP strategy

III.III. Outreach

ISU will serve as a center of the international space community as an international academy of space, inspiring and educating the public and stakeholders through branding and international action.

To ensure that ISU maintains a leadership position over the next 25 years, ISU must strategically change how it engages the space community, the general public, governments, agencies, and other key stakeholders. The outreach efforts are designed to enhance ISU's overall brand and then guarantee that ISU becomes a guiding force for the international

space community of 2040. ISU should focus on inspiring and educating its stakeholders and the public about the peaceful exploration of space. We propose that ISU achieve these goals in two phases. The first focuses on establishing the ISU brand more broadly from 2015 to 2025. The second focuses on using that established brand to take a new level of action until 2040.

During the branding phase, ISU should promote its image and activities on a global scale using social media and traditional media, by partnering with public figures, and by participating in conferences. ISU must get public support for increased space sector investment using popular online tools. ISU's extensive alumni network should also be used for this purpose, together with endorsement from inspirational public figures such as Neil deGrasse Tyson, Chris Hadfield, and others. ISU should advocate its position by becoming more involved at international and multidisciplinary conferences similar to the TEDx ISU conducted in 2012[48]. ISU could take initiatives to create its own conferences in a similar fashion to TED events.

ISU should develop an international academy, modeled on the USA's National Academy of Science which brings all of the top American scientists together to create "objective advice to the nation on matters related to science and technology"[49]. ISU would be an advisory council that helps set priorities across disciplines and nations in the space sector. As an independent organization, ISU would act as a neutral international space mediator, allowing for more communication and collaboration between countries such as the US and China. ISU would build interconnected space communities to serve as a global meeting place for peaceful ideas involving space.

By 2025, as shown in Figure III-3, we recommend moving into a more active phase, positioning ISU as an international mediator on space issues. In both phases, ISU will use its extensive alumni network[50], its experienced staff, and the 3Is philosophy to go from raising awareness to the delivery of advisory or consultation services. To raise awareness, we will use our presence at international conferences such as TEDx[48], our social media presence, and support from public figures[44] involving a marketing campaign to generate public support for space activities[51].

In conclusion, outreach to the space sector and the general public is an essential area in which ISU needs to invest resources for it to be a vital part of the future space sector. The strategies proposed are divided into the branding-centered phase, occurring from 2015-2025, and a more active phase, occurring from 2025-2040. We recommend that ISU revitalize and modernize its image and brand through the redesign of its media outlets, developing more open educational channels such as online access and conferences like TEDx, and create its own independent multinational and multidisciplinary space advisory service. This would allow ISU to have a meaningful impact on the space sector.
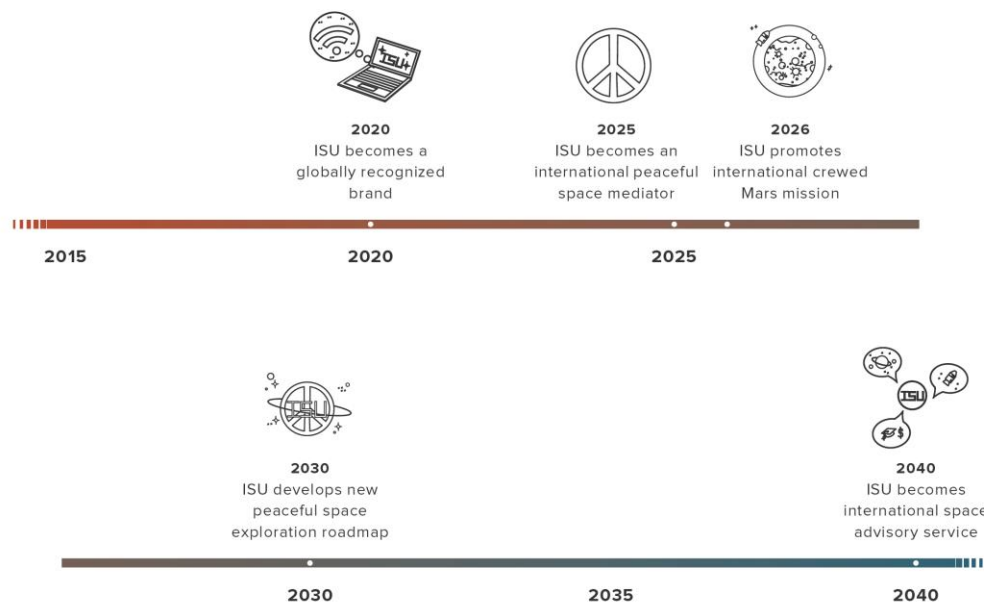

Figure III-3: 25-year roadmap for the Outreach strategy

III.IV. Startups

ISU was conceived in 1987 as an innovative institution to act as a beacon, bringing space-minded people together from all over the world, as stated in the ISU Credo[52].

From the beginning, ISU received support from the traditional space stakeholders, namely space agencies and major private corporations. In the last couple of decades, a new generation of space development, increasingly commercial, has arisen. This NewSpace with an agile approach to entrepreneurship is expected to have a predominant role in future space activities. While ISU has an indirect connection to space startups like Spire Global Inc.[53] through the initiatives of alumni, its current structure does not allow ISU to be a stakeholder in the emerging NewSpace sector, compromising its long-term sustainability. The main challenges ISU faces as an organization are related to the evolution of its internal culture. Generally speaking, organizations tend to lose their initial disruptive momentum and creative agility over time because of increased bureaucratic complexity and decision-making hierarchies. ISU can avoid this pitfall by building links between ISU and the commercial, space sector. The power of ISU lies in its alumni network that spans the space industry and agencies from around the world. The growth of the commercial space sector and the creation of new markets could potentially create knowledge and skill gaps in the ISU curriculum. At present, the institution does not retain any shares in the new private ventures that are founded by graduates. We propose the following strategies to support the creation and retention of an incubator program so that ISU can be an environment where new companies are created and thrive.

The broad strategy that ISU should adopt is the establishment of a new startup incubator system as part of the ISU institution. This startup incubator will be the core of a new for-profit ISU branch of the organization, while the academic part of ISU can remain a not-for-profit organization and continue to have the support of space agencies. ISU is currently registered as a not-for-profit under its academic mission. ISU participants often bring new knowledge and ideas to fruition, often in the form of new ventures. To attract investment for the creation of these new ventures, we recommend the creation of a for-profit organization following successful models like Singularity University[54] and famous incubators like Y Combinator[55].

The startup incubator will open the door for sizeable investments through the creation of two programs, one placed at the ISU campus in Europe and the other near Silicon Valley in the US. The use of the ISU main campus can lower the initial costs and infrastructure associated with the creation of a startup incubator. The incubator in Silicon Valley will be able to create new partnerships with many disruptive entities and talents located there. The incubators will expand over time to become a global network of incubators, with a network of mentoring alumni, strategic alliances, and investors. As each startup passes through the startup incubator, ISU will retain a percentage of the equity in the startup ventures. This creates a growing portfolio that can be leveraged for further investments in the startups or ISU.

The first stage of the startup incubator will comprise a program for space entrepreneurs lasting between three and four months, based on the model of other successful technology startup acceleration programs such as Y Combinator[55], where a large pool of resources will be provided to develop a minimum viable product (MVP) or proof of concept at the end of the program. A variety of resources will be available to participants including software, fast prototyping tools, and active mentorships. These mentorships will be provided by ISU alumni, staff, and industry professionals within the ISU network. The projects will be presented to a panel of investors at the end of the program. After the program, the startup incubator will serve as a host for two to three years for the new ventures, as this duration is the mean time to market for the products of the new startups. The new ventures will stay at the startup incubator building and have access to all the resources they need to develop their product. Unlike the first stage, the longer program will ask the companies to develop their businesses at an arm's length from ISU. After this period, startups will graduate from the incubator, and by then, they should be ready to put their first product to market and grow by themselves.

As part of the startup incubator, as the roadmap displayed in Figure III-4 shows, we envision the formation of an idea creation department for experimenting with new concepts that have the potential to disrupt the present state of technology. This department of the startup incubator is envisioned with two fundamental goals: to consider solutions that can provide radical improvements and to pursue radical ideas for a very limited amount of time to determine their feasibility and impact.

This idea creation department will have an approach similar to Google X[56]. An idea is adopted for a very limited amount of time to rapidly iterate on its feasibility and impact, and to free the researchers and developers from common concerns such as scalability and cost. After this initial period, the ideas will be either dismissed or pursued as startups in the incubators. In the long run, research on disruptive

technologies, such as artificial intelligence and nanotechnologies, should find refuge in and will be used by the idea creation department. Such topics could include disruptive technologies and their impact on society as a whole, as well as other groundbreaking questions. This approach will allow ISU to be at the forefront of major technological advances. The final aim of the startup incubator is to operate a idea creation lab in space by the year 2040. Parallel to the ISU acceleration program, we propose events like hackathons or Startupweekend[57] as a part of the startup incubator. These can serve as a catalyst to build up new teams and ideas that come into the acceleration programs. We could use a new facility in

Earth's orbit or on the Moon to operate as a creative space.

The overview effect, described by astronauts as a change in awareness after watching Earth from space, would create new mental perspectives on humanity[58] that could greatly change how businesses and products are developed, as well as how humans interact during these developments. In 2040, the need for imagination and creativity will explode when automation replaces traditional forms of work. The creative facility in space will fulfill those needs to develop creativity, imagination, and design. Through immersion in a space-based environment, participants will be able to envision a whole new set of products and services.
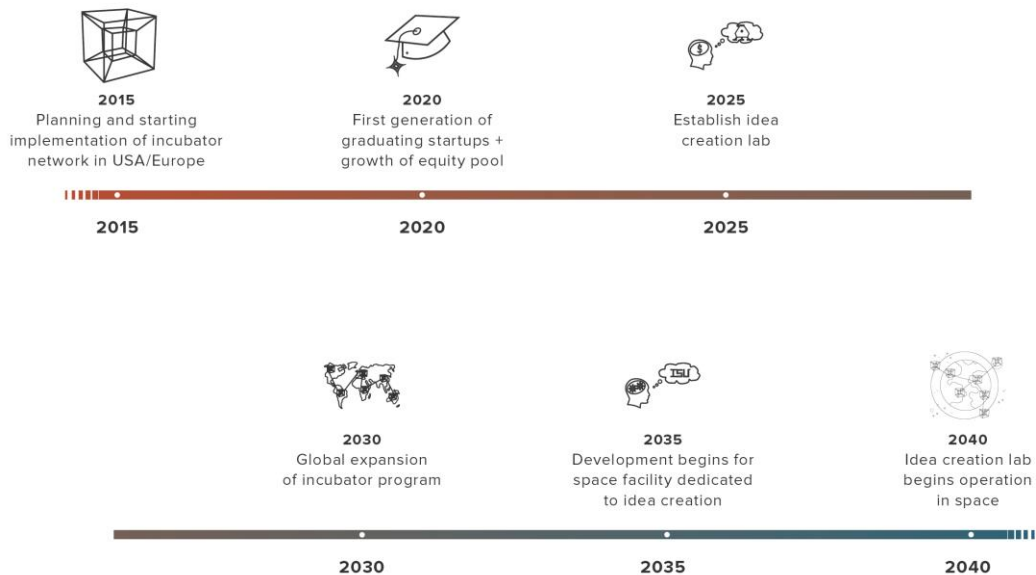

Figure III-4: 25-year roadmap for the Startups strategy

III.V. Analogs

Over the next 25 years, we forecast a consistent increase in human presence in space. Space analogs are a very important tool in the preparation and training of a society moving forward towards space.

In this paper, a space analog is defined as an area, habitat or procedure that aims to simulate certain aspects of a non-Earth environment, such as Low Earth Orbit, Moon, Mars, Asteroid environments or space missions, for training and testing purposes.

Due to the complex nature of space missions and ever-evolving technologies, there are always areas of each mission that require research. There are currently a number analog facility sites around the world run by various institutions, agencies or commercial entities that meet those research needs,

such as the Mars Desert Research Station (MDRS)[59]. To compete with these established analog facilities, the challenge lies in identifying a specific niche area for the proposed new analog facility that also meets the research needs of these emerging space missions. While this section mainly focuses on a strategy that ISU can follow, the proposed strategy may also be relevant and applicable to other institutions.

A roadmap with four phases of the analog facility was developed, as represented in Figure III-5. The first phase outlined a design and development plan to establish a permanent analog facility using existing resources such as ISU alumni already active in this area as well as current students and faculty. This phase would also serve as a learning experience, to allow ISU develop its analog testing and research

capabilities. In the second phase, it was planned that activities shall be extended and based on the experience learned from the first phase, to develop a new high fidelity analog facility and begin conducting analog missions. In the second phase, ISU would be on target to become a hub for analog research and training activity. By third phase in the 2030s, when more human presence in LEO is predicted, it was planned that ISU expands its activities in collaboration with partners, including training and research activities on existing commercial space stations. The goal of the fourth phase is to establish an ISU facility in Space by 2040, where the analog training will play a key role in training and preparations for long human deep space missions beyond Earth's orbit.

The future scenarios ranging from orbital stations to a human presence on Mars will rely heavily on analogs to prepare for space expeditions. Especially, as new areas of interest will expand, such as asteroid mining, lunar bases or human deep space missions, it is imperative to better prepare for such emerging industries.

A permanent analog facility offers training opportunities for students at ISU but would also provide a unique outreach and an opportunity for STEAM education.

There is also scope for ISU to offer commercial hiring schemes of the analog facility to companies interested in testing their experiments and hardware in a high fidelity environment as well as a training platform for future space tourists.

It is expected that in the coming years there will be a greater demand for properly trained space travellers, resulting in a growing need for crew selection and training programs. The proposed analog facility in the framework of the International Space University can meet that growing need.

The strategy to establish an analog facility at ISU, involves using the ISU alumni network, partner companies, and space agencies, to carry out analog projects that pave the way for space exploration. Although there are several educational institutions, government agencies, and commercial entities across the globe already carrying out space analog missions, ISU has the opportunity and support structure to develop innovative analog experiments, thanks to its 3Is philosophy and its outstanding network of alumni professionals. This strategy does not strive for a competitive relationship with these entities, rather a contribution to necessary research for successful future space missions. By providing such an analog facility, ISU can become the institution for expertise for the space community, in leading humanity towards a multi-planetary existence.
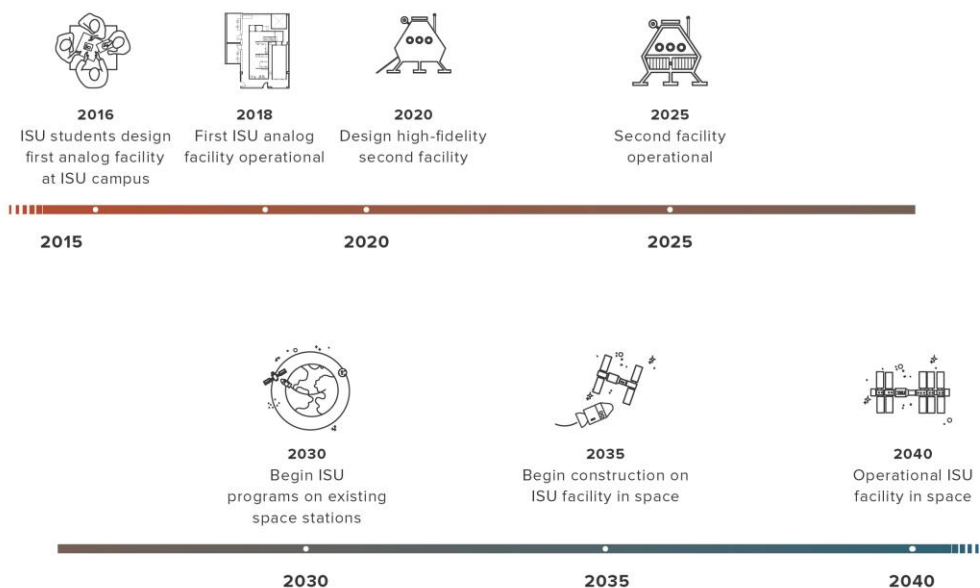

Figure III-5: 25-year roadmap for the Analogs strategy

IV. CONCLUSION

Vision 2040 began with thorough research of the current trends in the space sector and its broader context. From this analysis, we built a set of recommended strategies for ISU to grow its leadership role amongst the space community, serving as a hub that brings together alumni and influences policy makers, scientists, and businesses. Our plan would allow ISU to continue to provide space education that help humanity drive itself further beyond Earth and out towards the stars.

We identified five future scenarios that, jointly or independently, will most likely come to define the next 25 years of the space sector: real-time Earth applications, orbital stations, lunar settlement, lunar and asteroid mining, and a human presence on Mars. Each of these five scenarios presented clear signals of change in the space sector. The emergence of NewSpace companies, emerging space-faring nations, disruptive technologies, and increasing global connectivity, will all continue to have an intrinsic impact on the great potential of space. We believe that ISU can be a catalyst for innovation, not only riding this wave of change, but also using it to accomplish the dreams embraced in the ISU Credo. ISU should foster and stimulate space exploration, and eventually bring education into space itself, changing forever the concept of education.

To contribute to achieving the five envisioned scenarios, ISU must recognize and overcome technological challenges around life support systems, propulsion, big data analysis, as well as cultural challenges such as online education, access to space, public support, government support, international cooperation, and the involvement of the private sector. To address these challenges successfully, we identified and analyzed several representative skills critical for future space professionals. These included: entrepreneurship, communication and negotiation, STEAM education, international cooperation, big data analysis, CubeSat design, life support systems management, advanced spacecraft technology development, in situ resource utilization, public outreach, crew selection and training, and space policy. The combination and grouping of skills led to the creation of our strategic areas of focus that could address potential future skill gaps.

We devised five strategic areas of focus to provide the identified skills: the future of SSP, analogs, outreach, alumni, and startups. Each strategy outlined a 25-year roadmap of actionable items to help ISU to continue shaping the future space sector. The strategic plans encompassed a variety of enabling actions such as building analog facilities in the Strasbourg campus, organizing TED-like conferences, creating startup incubators, embracing online education with a renewed SSP format, and transitioning the alumni network into a true space family. For all these actions, we have identified potential partners with which ISU could work and methods for tracking the successful accomplishment of the plans.

The strategies we provide deviate ISU from its current role as an international university, and encourage it to embrace a number of additional roles in the future. Implementing any of these strategies may require a re-examination of the current management structure, financial status, and organizational motivations. For example, our startups strategy requires ISU to create a for-profit branch that would require new management and leadership.

We hope that ISU will take the lead in this evolving environment by providing the necessary information and tools to its participants, partners, and stakeholders. We believe that ISU should commit itself to rethinking education around a new set of skills and ideals, combining the 3Is through the future of SSP, analogs, outreach, alumni, and startups.

Since its inception, ISU has been an institution known for pushing the boundaries of education towards new frontiers. With these roadmaps in hand, it will continue to do so well into the 2040s.

V. AKNOWLEDGEMENTS

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